[redacted]

32 p

[redacted]

AVAILABLE TO [redacted]

Technical Report No. 32-31

Juno Final Report, Volume III, Juno II: Earth Satellites (U)

(Title Unclassified)

C. F. Mohl 28 June 1962 32p refs

[2] (NASA Contract NAS7-100) NASA CR 52802

(NASA CR-52802; JPL-TR-32-31)

(NASA-CR-52802) JUNO FINAL REPORT, VOLUME III. JUNO II EARTH SATELLITES (Jet Propulsion Lab.) 32 p

N79-76247

Unclas

00/15 11044

[redacted]

(NASA CR OR TMX OR AD NUMBER) (CATEGORY)

JPL

JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA

June 28, 1962

~~This document contains information affecting the national defense of the United States, within the meaning of the Espionage Laws, Title 18 U.S.C., Sections 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.~~

[redacted]

CLASSIFICATION CHANGE

To UNCLASSIFIED

By authority of GDS-64-1 Date 11

Changed by A. Shirley

Classified Document Master Control Station, NASA

Scientific and Technical Information Facility

[redacted]

Technical Report No. 32-31

Juno Final Report
Volume III

Juno II: Earth Satellites
(Title Unclassified)

C. F. Mohl

AVAILABLE TO U.S. GOVERNMENT AGENCIES ONLY

Charles W. Cole

Charles W. Cole
Juno Project Director

[redacted]

Copy No. 00347

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

June 28, 1962

GROUP 4 ~~Downgraded at 3 year intervals; declassified after 12 years.~~

[redacted]

Prepared Under Contract No. NAS 7-100
National Aeronautics & Space Administration

~~This document contains information affecting the national defense of the United States, within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.~~

[redacted]

CONTENTS

TABLES

FIGURES

FIGURES (Cont'd)

PREFACE

Technical Report No. 32-31, which is prepared in three volumes, is a summary of Jet Propulsion Laboratory space-flight activities utilizing the *Juno I* and *Juno II* rocket-vehicle configurations.

Volume I describes events beginning in 1954 which led to the launching of *Explorer I,* America's first satellite, and carries the story down through *Explorer V.*

Volume II describes the *Juno II* rocket vehicle and the program which led to the *Pioneer III* launching and culminated in the flight of *Pioneer IV,* America's first successful lunar probe.

Volume III is concerned with the final phase of the *Juno* program; it summarizes the entire program, and describes in detail eight launchings.

The general program presented in Volume I, and most of the work presented in Volume II, was conducted under sponsorship of the Department of the Army, Ordnance Corps, Contract No. DA-04-495-Ord 18. Shortly before the *Pioneer IV* flight, the program was transferred to the National Aeronautics and Space Administration, Contract No. NASw-7.

[redacted]

ABSTRACT

11553

This report is the third and final volume of a series of reports covering the *Juno* program, which had for its objective the launching of Earth satellites and space probes. Basically, the vehicle consisted of a booster of either a modified *Redstone* or a modified *Jupiter* and upper stages of scaled-down *Sergeant* solid-propellant motors. A total of 19 launchings were involved in the *Juno* program; Volume III of this series describes eight of these launchings and covers the period between March 1959 and May 1961. The six different payloads used are described, as are each of the eight firings. Cry. Author

I. INTRODUCTION

This report is the third of a three-volume series covering the *Juno* program (see Ref. 1 and 2) and the Jet Propulsion Laboratory's participation in early spacecraft activities. This volume covers the *Juno II* Earth satellite launchings that followed the *Juno II* space probes (*Juno* Final Report, Volume II). This series of launchings involved eight very similar *Juno II* vehicles and six different types of payloads (as shown in Table 1) and covered the period between March 1959 and May 1961.

Aside from some early studies on satellite trajectories carried out for the Navy in 1945 and 1946, the first direct participation of JPL's space-flight activities occurred in the joint Army-Navy Project Orbiter studies in 1954 and 1955 when Army Ordnance Corps asked JPL to assist in the preparation of a feasibility study for a rocket vehicle capable of orbiting a small payload around the Earth. Also at that time, as part of a re-entry test program, the missile laboratories at Redstone Arsenal were in the process of developing a modified high-performance version of the *Redstone* missile. This modified missile, as the first stage booster for a three-stage solid propellant cluster (JPL), became the basis for the Army proposal for a satellite vehicle. As part of the feasibility study for the development of an orbiting missile, JPL also conducted an investigation into the problem of instrumenting such a missile. This investigation culminated in a JPL proposal to determine the trajectory of an orbiting missile using radar techniques.

Actual development of the orbiting vehicle, as described in the feasibility studies was never authorized as Project Orbiter was cancelled in August 1955 when the Vanguard Project was established. However, the need for obtaining re-entry test data still remained, and Redstone Arsenal (Army Ordnance) continued work toward this objective.

[redacted]

Table 1. Description of *Juno II* Earth satellite launchings

Round	Date	Stages	Payload
16	7/16/59	4	IGY
19B	8/14/59	3	Inflatable sphere
19A	10/13/59	4	IGY
19C	3/23/60	4	Van Allen
19D	11/3/60	4	Ion probe
19F	2/24/61	4	Ionosphere beacon
19E	4/27/61	4	Gamma Ray astronomy
19G	5/24/61	4	Ionosphere beacon

In support of the re-entry test vehicle program, JPL continued to work on the development of high-speed stages, but this development was now keyed to the Redstone re-entry test program rather than the satellite program, and the objectives and development schedules were modified accordingly. In following these objectives, JPL developed a two-stage cluster of *Sergeant* solid-propellant motors that could be utilized with a modified *Redstone* first stage to satisfy the re-entry test problem.

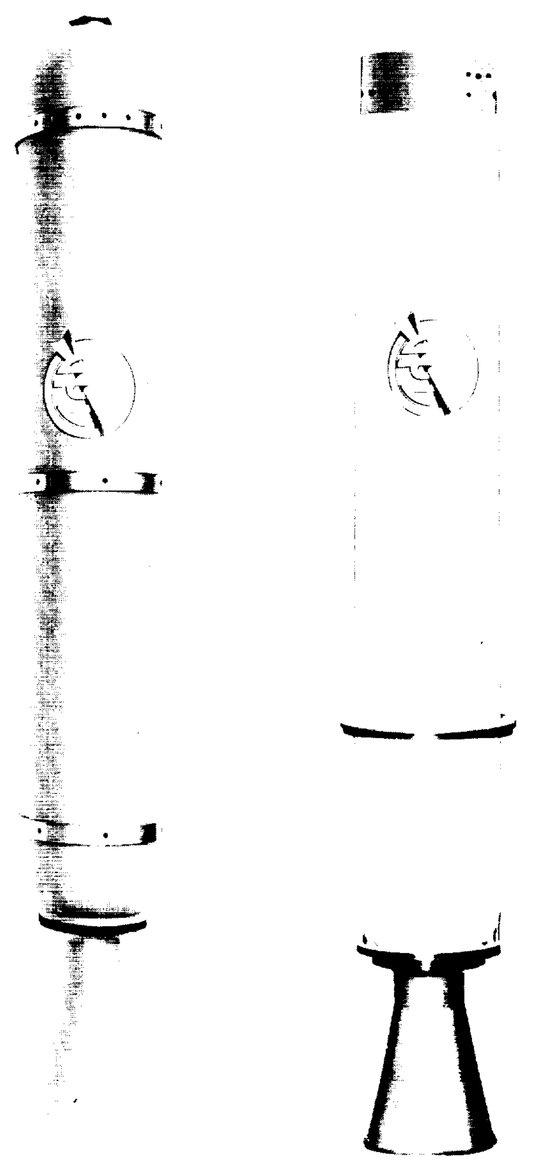
Although the major effort of the laboratory had been directed to solving the re-entry vehicle design, some analysis was undertaken to explore the growth potential of the high-speed stages. On the basis of this analysis, it appeared that with some minor structural modifications, the addition of a single solid-propellant motor (Fig. 1) as a third solid propellant stage, and some development work on the existing solid propellant motors, the high-speed stages would be capable of launching significant payloads into orbiting trajectories.

The RTV program was concluded in August 1957 with the successful recovery of a scale IRBM nose cone. Three rounds had been fired. The first, round 27, was successfully fired in September 1956 to test the basic vehicle without a re-entry type nose cone.

The next round (34) had a guidance malfunction, and the nose cone impacted too far from the target area to be recovered; however, the following round (40) impacted very close to the target area, and the nose cone was recovered intact.

Volume I (Ref. 1) of this series of reports covered the early history of the program, a detailed description of the high-speed stages, the Microlock tracking and telemetry system, and the launching operations of the RTV and *Juno I* rounds. There were nine launchings involved in the RTV and *Juno I* series, and these are tabulated below (Table 2).

Volume II (Ref. 2) of this series of reports covered the space probes (*Pioneers III* and *IV*) launched on the initial *Juno II* vehicles. Volume II also gives detailed description of the payloads (space probes) and of the basic launching vehicles. The launching vehicle used for the space probes is very similar to the vehicle used for the *Juno II* Earth satellite launchings described in this report. The results of the space probe launchings are tabulated in Table 3.



a. SECOND-AND THIRD-STAGE MOTOR

b. FOURTH-STAGE MOTOR

Fig. 1. Solid propellant motors

Table 2. RTV and *Juno I* launchings

Program	Flight or round and date	Duplicate designations	Stages	Mission	Results
RTV	Round 27, Jupiter-C 9/20/56		3	Proof test of re-entry test vehicle and Microlock	Successful Range: 3300 mi. Height: 650 mi.
RTV	Round 34, Jupiter-C 5/15/57		3	Nose cone test and recovery	No recovery of nose cone
RTV	Round 40, Jupiter-C 8/8/57		3	Nose cone test	Successful recovery of nose cone
Juno I	Round 29, Jupiter-C 1/31/58	*Explorer I* 1958 Alpha	4	Earth satellite	In orbit
Juno I	Round 26, Jupiter-C 3/5/58	*Explorer II*	4	Earth satellite	Fourth stage did not function
Juno I	Round 24, Jupiter-C 3/26/58	*Explorer III* 1958 Gamma	4	Earth satellite	In orbit
Juno I	Round 44, Jupiter-C 7/26/58	*Explorer IV* 1958 Epsilon	4	Earth satellite	In orbit
Juno I	Round 47, Jupiter-C 8/24/58	*Explorer V*	4	Earth satellite	Failed to orbit
Juno I	Round 49, Jupiter-C 10/22/58	*Deal III* *Beacon*	4	Earth satellite	Failed to orbit

Table 3. *Juno II* space probe launchings

Program	Flight or round and date	Duplicate designations	Stages	Mission	Results
Juno II	Round AM-11 12/6/58	*Juno IIA* *Pioneer III*	4	1. To establish trajectory.	Failed to obtain escape velocity; however, its highly elliptical trajectory (63,500-mile apogee) provided excellent measurements indicating the existence of the outer Van Allen belt.
				2. To measure cosmic ray radiation. 3. To test communications to extended ranges. 4. To test engineering devices that would be useful on later rounds.	
Juno II	Round AM-14 3/3/59	*Juno IIA'* *Pioneer IV*	4	Same as above.	Successful. Maximum communication distance—407,000 miles. Information obtained on radiation levels in cis-lunar space as well as in the Van Allen belts. De-spin mechanism tested successfully.

II. *JUNO II* LAUNCHING VEHICLE

The launching vehicle for the *Juno II* Earth satellite missions was essentially the same vehicle used on the *Juno IIA* and *IIA′* (*Pioneer III* and *IV* as reported in Vol. II). However, some structural modifications were necessary to accommodate the heavier payloads, and in the case of round AM-19B, the vehicle was designed without a fourth stage.

The basic flight plan was essentially the same as that followed in the *Juno I* and the space probe launchings: separation of booster from the guidance compartment (with the high-speed stages attached) after burnout, shroud ejection during early coast period, guidance compartment stabilization, and ignition of the high-speed stages.

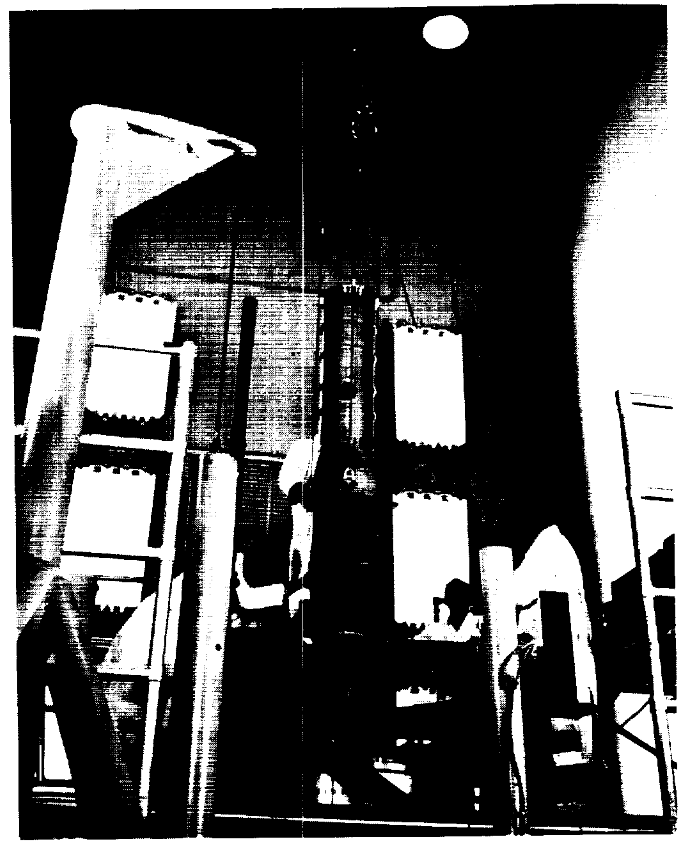


Fig. 2. Cone support structure

A. Basic Design Modifications

When the *Juno* program progressed into the *Juno II* Earth satellite phase, several vehicle and payload design considerations were necessary to accommodate the increased payload weight (75-100 lb satellites).

In the vehicle area, the main design effort was to raise the resonant frequency of the composite cluster-booster. Early experiments showed that the cluster could be appreciably stiffened by supporting stage 4 with a cylindrical support (Fig. 2) built up from the stage 3 cone. In addition to this support, six 4-in. nylon rollers were installed on the inner side of the shroud support at the level of the top of the rotational launcher, Fig. 3. The combination of the cylindrical support on stage 3 and the nylon roller bearing on the shroud supporting stage 2 raised the first cantilever mode frequency to approximately 10 cps. Most of the clusters used in this series had a spin rate of less than 450 rpm.

Stage 4 was fitted with a head-end adapter to make it compatible with the cylindrical launching cylinder on stage 3 (Fig. 4). This adapter also served as the mating flange for the stage 4 payload interface.

Fig. 3. Cluster roller assembly

B. First Stage

The modified *Jupiter* booster used in this series consisted of the main body section with its propulsion system and the instrument compartment which housed the guidance spatial attitude control, the events programmer, tracking devices, the cluster drive motors, the cluster tube or rotational launcher, and the shroud.

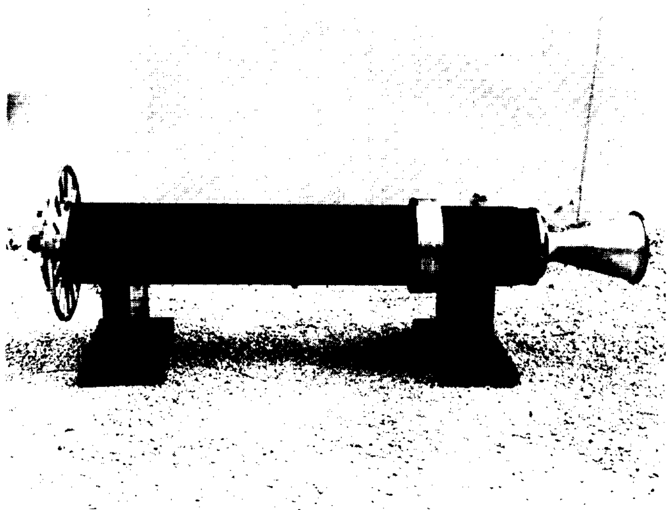


Fig. 4. Modified fourth stage

The air frame used on this missile is a semi-monocoque cylindrical shell and is essentially the same as the air frame in a production type missile except that the tank section has been elongated 36 in. for increased burning time. The power plant used is a NAAS-3D liquid propulsion engine which develops 150,000 lb sea-level thrust using RP-1 fuel and LOX (liquid oxygen). The engine is equipped with a gimbal mechanism operating in two planes to control the missile in pitch and yaw. Hinged turbine exhaust nozzles control roll.

C. Guidance System

After burnout, the main body section (thrust units and tanks) is separated from the rest of the vehicle. Figure 5 shows the main assemblies and overall sequence of events. Separation was accomplished by firing spring-loaded explosive bolts used to fasten the main body to the instrument compartment. Retrorockets located in the aft section of the main body are then fired to provide a substantial velocity difference between the two bodies to preclude any possibility of bumping.

The shroud is then separated from the guidance compartment (by firing spring-loaded explosive bolts) and pushed out of the guidance-compartment path by firing a small rocket to exert a side force. During the remainder of the coasting period, a spatial attitude control system positions the instrument compartment so that the high-speed stages can be launched on a proper trajectory. This control system uses compressed air through eight air jets, tangentially located on four fin-like protuberances at the aft end of the instrument compartment.

D. High-Speed Stages Rotation Launcher

The rotational launcher for the high-speed stages is permanently attached to the forward end of the instrument compartment. The launcher drive motors and their power supply are housed within the instrument compartment along with the launcher rpm control equipment.

E. Second Stage

The JPL high-speed second stage used on this vehicle essentially consists of eleven scaled-down *Sergeant* motors each containing approximately 50 lb of T17-E2 solid propellant composed of a polysulfide (rubber-type) fuel with an ammonium perchlorate oxidizer.

Each rocket motor contains an igniter, composed of two electric matches (DuPont type S-88) wired in parallel and a jelly-roll of metal oxidized material encased in a plastic sheath.

The motors (Fig. 6) are arranged in an annular ring about a center tube and held in position radially by three transverse bulkheads. On the base of this center tube is a carefully machined ring which is mated to a similar ring at the base of the rotational launcher. The axial load is carried by this center tube, while transverse support for the cluster is provided by a ring on the forward section of the rotational launcher having guides that engage mating surfaces on the forward bulkhead of stage 2.

Stage 2 receives its ignition current from batteries located in the instrument compartment when a programmer in the instrument compartment reaches a preset time.

F. Third Stage

The third stage (Fig. 7) also utilizes scaled-down *Sergeant* motors; however, the propellant is a higher performance polysulfide JPL 136. The igniter is identical to that used in stage 2.

Stage 3 is formed by a bundle of three of these motors held by three transverse bulkheads with the motor cases carrying the axial loads. A cone-support structure and a cylindrical support (Fig. 2) is attached to the forward bulkhead of stage 3 to provide a support and launching structure for stage 4. However, AM-19B did not utilize a fourth stage, and therefore only the conical support was used as a base for the payload. The only other round in this series that did not utilize the cylindrical support in addition to the conical one was AM-19C. In this case the payload was very light (22.5 lb), and the additional

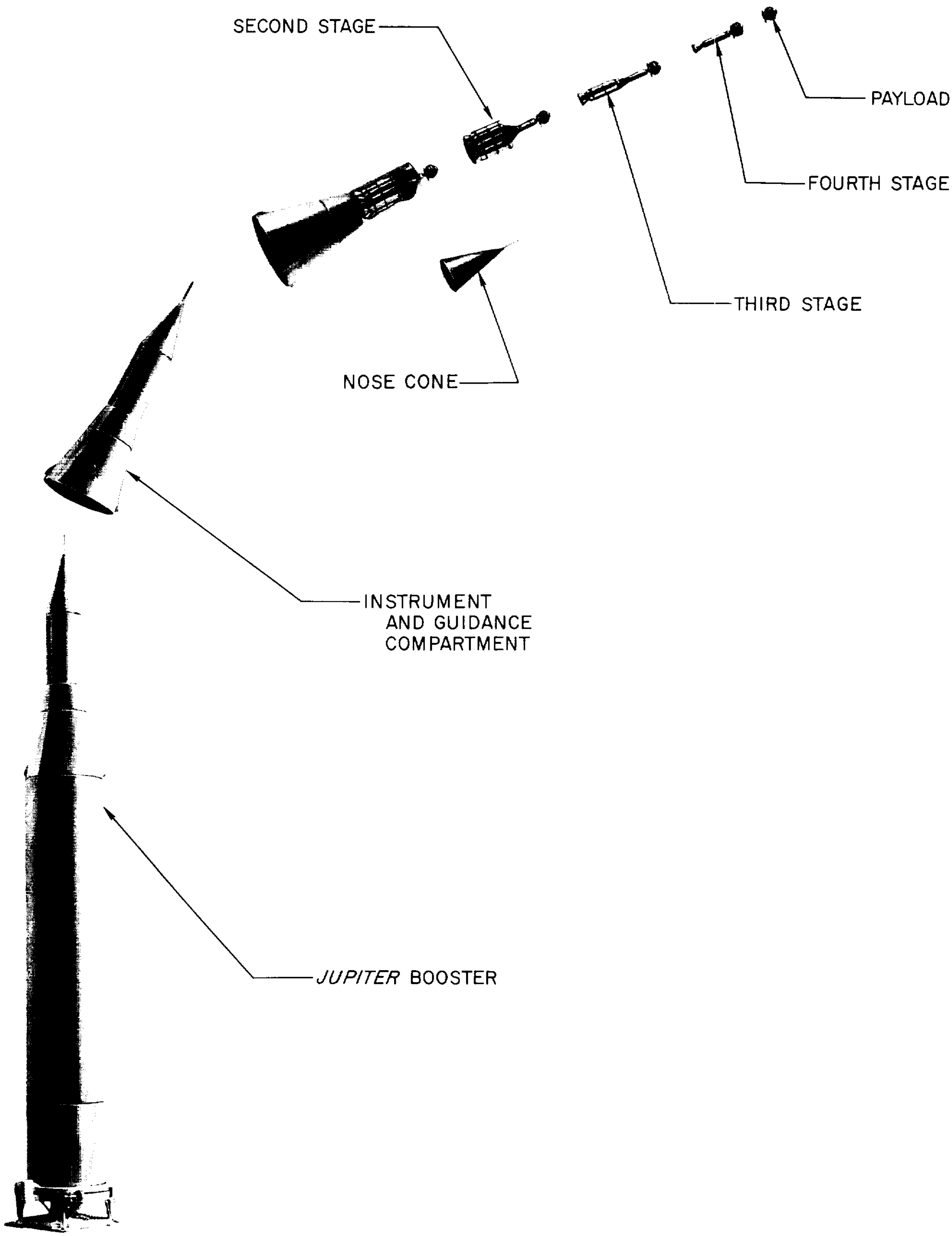


Fig. 5. Main assemblies and sequence

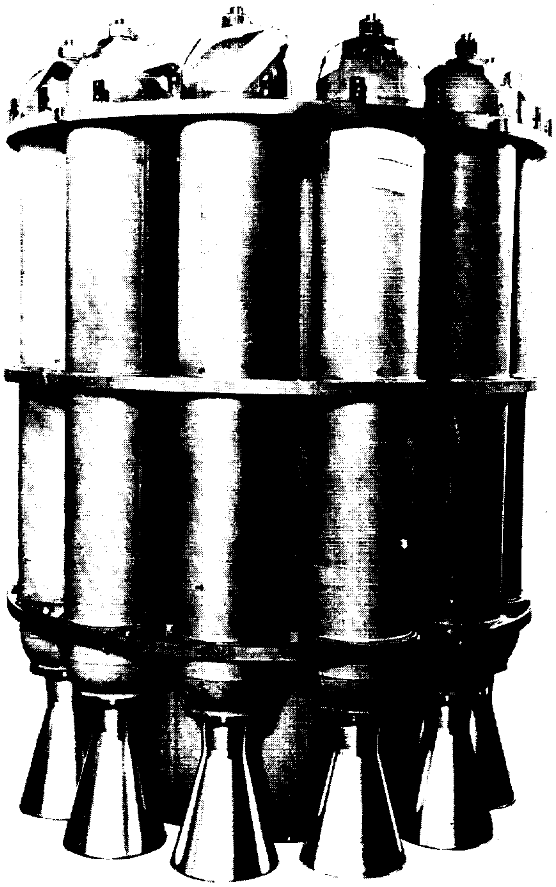


Fig. 6. Stage 2 motor assembly

rigidity afforded by the support cylinder was not needed, whereas the need for saving weight was imperative.

The ignition of stage 3 is controlled by a motor-driven 20-sec timer located near the base of the fourth-stage launch cone. The timer is started by the closure of either one of two pressure switches (mounted on two of the stage 2 motors) when stage 2 is ignited. Approximately 9 sec after the timer starts, it completes a circuit that fires stage 3 (from batteries carried in the timer assem-

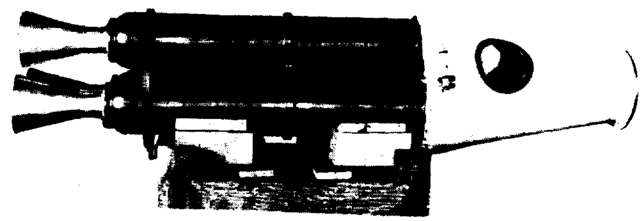


Fig. 7. Stage 3 motor assembly

bly on stage 3). In this series the timer was modified as shown in Fig. 8 to facilitate easier handling methods in the field.

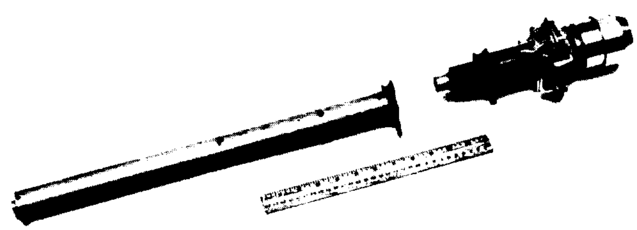


Fig. 8. Timer, ignition

G. Fourth Stage

The motor used in this stage is similar to those used in the other stages and, unlike the *Pioneer* space probe series, it is made of 410 steel rather than titanium. The propellant in this motor is JPL 532A, a high-performance polyurethane propellant.

The ignition of stage 4 is provided by a battery controlled by the same timer that fired stage 3. Ignition occurs approximately 9 sec after the ignition of stage 3.

III. *JUNO II* PROGRAM REVIEW

Of the four attempts to launch Earth satellites in the *Juno II* program, three (AM-16, AM-19B, and AM-19C) failed to achieve orbital conditions. Two of these failures were attributed to the launch vehicle system and one to the cluster system. Accordingly, in the summer and fall of 1960 a thorough review of all elements of the *Juno II* system was conducted. The JPL portion of this review consisted of a detailed engineering analysis of the *Juno II* cluster in an effort to provide the largest probability of success for the remaining vehicles. This analysis, made in September and October 1960, consisted of a review of the following four areas:

1. Hardware condition, ground assembly and checkout procedures, inspection and balancing procedures, and general quality control.
2. Design modifications and structural or hardware changes.
3. Engineering telemetry.
4. Dispersion analysis, correlation, and prediction.

At the initiation of this review, 15 clusters had been launched on two types of boosters; thus, a good portion of the review was based on flight experience.

Each subsystem and area of the cluster was examined in detail in an attempt to locate any incipient causes of future failures. Special attention was given to those areas which might have contributed to past failures. While no individual item was found to be defective, several recommendations were made and implemented, reflecting a general upgrading of the quality of the installation. These recommendations were in the areas of alignment, balancing, cable routing and tiedown, handling, and inspection.

The cluster system was initially designed for smaller payloads than those being flown in the *Juno II* satellite program. Although the structure and configuration were judged adequate to meet the design conditions, new designs were investigated to improve weak points. These designs provided a more rigid structure, larger separation clearance angles, increased gas venting on separation, and better accessibility. No new design was appreciably lighter than the existing configuration. These redesigns were not incorporated because of the short schedule and small number of flights remaining as well as the serious possibility of introducing new and unexpected sources of failure.

The possibility of installing a telemetry system capable of providing engineering information on the separation and flight dynamics was considered. It was found that the vehicle's limited weight capability precluded the installation in the payload or cluster of any really worthwhile telemetry. The use of booster telemetry to monitor stage 2 ignition was rejected on the grounds that propulsion ignition malfunction could be determined from tracking data and that coupling the ignition system and the telemetry system at this late date would decrease ignition reliability.

A study was made of the general cluster dispersion problem in an effort to correlate past performance, isolate the major causes of this dispersion, and predict the behavior of future flights. (See Table 4.) Dispersion angle of the cluster (the angle between the actual velocity vector at time *t* and the velocity vector obtained from a perfect cluster fired with the same stage 2 launcher constraints) is a function of booster instrument compartment pitch and yaw rates, cluster spin rate, cluster balance, thrust malalignments, thrust, mass flow, ignition and tailoff, motor-to-motor variations, stage pitch to roll moment of inertia ratios, stage-to-stage principal axis malalignments, cluster stiffness, and payload weight. Some of these parameters have been different for different payloads. In addition, the dispersion angle of the cluster is a function of the precession-period-to-burning-time ratio, the precession period to duration from stage-to-stage ignition, and the phase of the nutation angle at the instant of motor burnout. It was found to be impossible to compute accurately the dispersion of a particular round. This was due to the inability to accurately establish the geometric and mass parameters of the cluster as a function of time as well as dynamic effects in the cavities during separation, stored elastic energy, stage 4 nozzle (igniter and timer) blockages, as well as geometric and mass parameters of the cluster.

Flight results could not be correlated specifically because of the almost complete randomness of most of the previously mentioned dispersion-causing parameters. This large number of random effects, most of which are in series with each other, leads to a fairly wide statistical distribution of dispersion angles. The difference in probability between the most probable dispersion and a dispersion factor of $\frac{1}{2}$ to 2 different is extremely small.

A range of possible, probable dispersions (0 to 6 deg) was computed and all (non-aborted) flights fell within this range. The small number of flights compared to the number of random variables precludes any correlation of specific rounds. The overall conclusion is that the flight dispersions observed to date are representative of the magnitudes of similar future rounds and that these dispersions are normal for this vehicle.

Table 4. Cluster dispersion summary

Number of flights	General results	Detailed comments	Round number	Actual rpm	Actual dispersion	Computed dispersion
3	Successful	a. Final dispersion, 2 deg	29	750	1.2°	3.3°
		b. Dispersion per stage, low	44	750	0.76	3.3
		c. Roll rate of stage 4 dropped 25%	47		+	
3	Successful, but with high dispersion	a. Final dispersion, 5-7 deg	24	750	4.8	3.3
		b. Dispersion per stage, high	AM-11	405	4.7	7.9
		c. Stage 4 roll rate dropped 25% on one flight; no record on others	AM-14	560	4.6	4.3
2	Failures	a. Electrical or ignition malfunction				
1	AM-19 (heavy payload)	a. Final deviation less than 2 deg	AM-19A	428	0.76	0.38
		b. Dispersion per stage, small				
		c. Stiffened structure				

IV. *JUNO II* EARTH SATELLITE LAUNCHINGS

The field operations during May–October 1959 were concerned with the preparation and firing of rounds AM-16 and AM-19B whose missions were to orbit a multipurpose scientific payload (Fig. 9) and a 12-ft diameter inflatable sphere, respectively. Neither effort was successful.

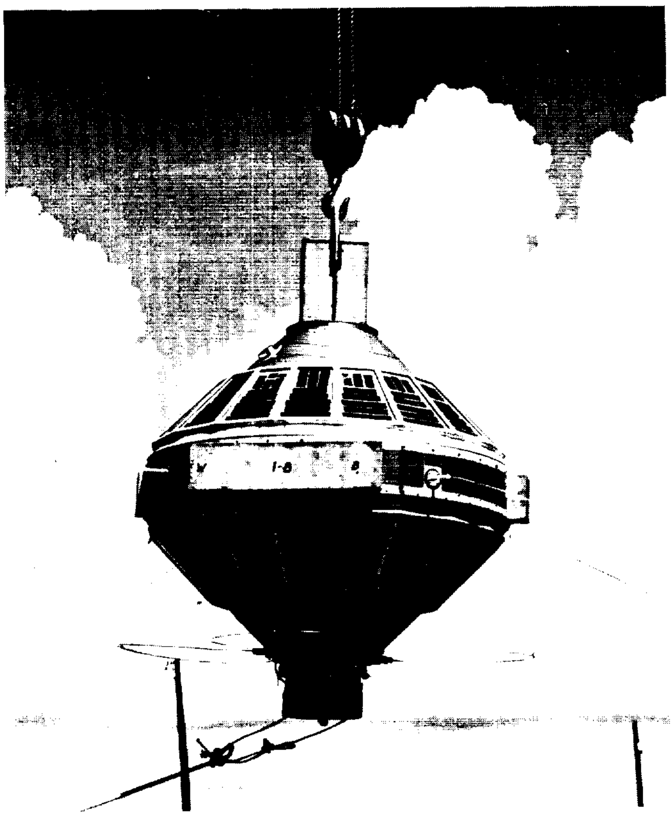


Fig. 9. Multipurpose payload, AM-16

The Laboratory's efforts in preparing cluster 14 of the high-speed stage for the AM-16 launch and cluster 15 and the payload for the AM-19B launch are described below.

A. *IGY Satellite (Round AM-16)*

Cluster 14 was received at the Cape on May 16, 1959, and was stored until May 20 when it was unpacked, inspected, and the launcher drive motor gear system changed to a ratio of 17.7:1. Cluster assembly, alignment and balancing through assembly IV proceeded in a normal manner with no serious difficulties. Alignment checks with payload 2 on the cluster showed an undesirably large runout, necessitating a shim between the payload and the separation joint. Final runout on the payload was 0.0025 in. The two cluster vibration accelerometers were again added to this cluster. The basic system as used on AM-14 was modified to improve frequency response and to reduce the interference previously encountered.

The cluster electrical checkouts proceeded in a satisfactory manner, disclosing several difficulties that were corrected before flight. Several finger contacts on the assembly IV motor showed intermittent shorting to the motor case. This difficulty was finally traced to metal chips in the hollow aft launch ring that were coming in contact with the bolts holding the finger contacts onto the motor. An additional problem was encountered with the assembly II accelerometer breakwire modules in that the fine piano wires were corroding to such an extent that electrical continuity was no longer obtained. These modules were replaced.

On June 16, 1959 the decision was made to return one of the payloads to ABMA in order to complete two weeks of environmental testing under vacuum conditions. Field operations were resumed again on July 6 with another check with the payload on the cluster. With the satisfactory completion of this and other final tests, preparations were made to install the cluster and payload on the booster.

1. RF Spin Test

The cluster was moved to the pad (Fig. 10) at 0700 EST on July 9, 1959, and after an hour's delay, necessitated by minor mating problems, was satisfactorily mated with the booster. Prior to installing the payload, wiring errors were discovered in the payload simulator. These errors had to be corrected before a satisfactory check of the payload control system could be made. During the actual spin test no difficulties were encountered with the cluster system. The two cluster accelerometers' signals were monitored at the telemetry ground station, and although a cyclic variation similar to that found on the AM-14 spinup was noticed, the level was only 4% of full bandwidth.

2. Flight Test

The additional complexity of the payload and necessity of having 99% of the payload and cluster work completed

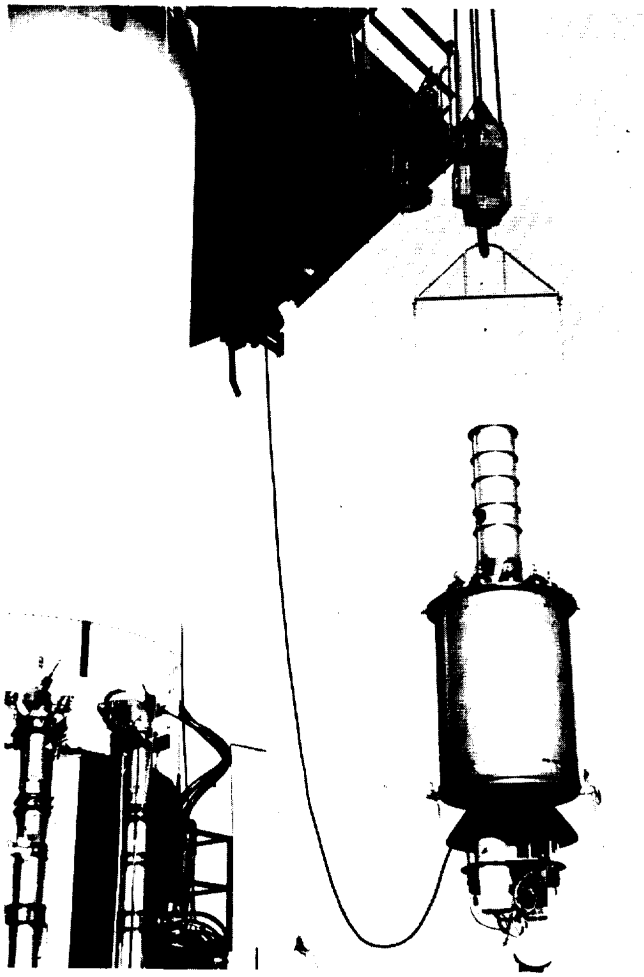


Fig. 10. High-speed stages, AM-16

before the 2½ hr required for shroud installation and roller adjustment could commence resulted in an extremely long countdown. The igniter installation was shifted to the early rf-silence period in an attempt to get assembly IV and the payload on earlier. Even so, the count required 700 min plus a built-in hold of 60 min in order to ensure that the prescribed firing time tolerances could be met.

3. Countdown Operations

The countdown operations started fairly smoothly, although difficulties encountered during the preparation of the payload delayed payload delivery at the pad about 1½ hr. Most of this time was recovered, and it was only necessary to delay LOX loading at X − 220 for 20 min. During payload rf checkout, a peculiarity was noted in the 108-Mc signal containing the micrometeorite experiment data. The Microlock receiver was apparently losing lock because of the nature of the sampled data, and in addition the carrier frequency was shifted during the sampling period. It was believed that the doppler data, and hence the early orbit determination, would be marginal. Since the payload would have to be returned to ABMA for reworking, the decision was made to go ahead with the launching.

A faulty pitch gyro was found during the guidance system checkout and replacement required a 50-min hold at X − 100 min.

At X − 47 sec a 13-min hold was required to clear the pad area prior to turning on all rf equipment.

At X − 50 sec a 4-min hold was called by the range when the Range Safety Vertical Wire Sky Screen operator lost phone contact with the Range Safety Office. The countdown was recycled at X − 2 min and held for 10 min to check guidance pre-settings. Liftoff occurred at 1237:03:18 hr EST July 16, 1959.

4. Launch

At liftoff the missile deviated to the west in an obviously erratic manner. Cutoff and destruct commands were sent by the Range Safety Officer at about 5½ sec of flight. Impact occurred about 250 ft northwest of the pad 5 launch table and 300 ft southwest of the blockhouse. Personnel at the blockhouse window had observed at least one upper stage rocket motor burning at both ends after missile destruct; most of the solid propellant and all booster Ordnance items were consumed by the ensuing fire after impact. Cluster motor cases, the instrument compartment, and payload were found within a circle of less than 100-ft diameter. Figures 11, 12, and 13 show assembly II and launcher, assembly III, and assembly IV, respectively. No propellant was found during the initial examination, but on closer scrutiny the following day, several pieces were found totaling about 5 lb. This propellant, as well as most of the rocket motor cases and other cluster parts, was returned to JPL for examination.

Preliminary investigation of telemetry records and of components recovered from the wreckage indicated that inverter 1 had ceased to deliver power to the guidance system at liftoff due to a short between the cases of two diodes in inverter 1 voltage regulator.

B. Twelve-Foot Inflatable Sphere (Round AM-19B)

The purpose of the inflatable sphere experiment was to determine the characteristics of the upper atmosphere

Fig. 11. Assembly II and launcher, postflight

Fig. 12. Assembly III, postflight

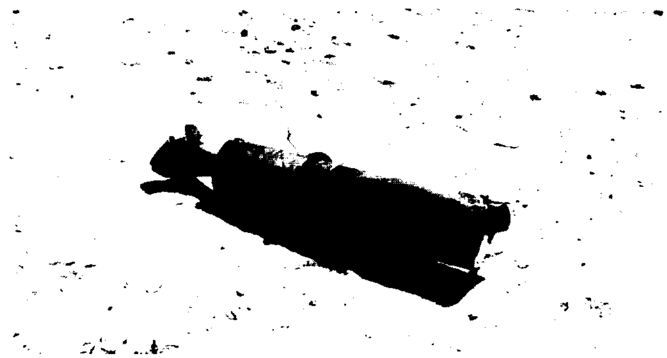


Fig. 13. Assembly IV, postflight

in the region between 100,000 and 500,000 ft. To aid in the gathering of data an inflated sphere having a minimum lifetime of 40 days was to be used. The payload preparation at JPL started early in March 1959, and ran through the middle of July. However, a completed payload had to be available early in June for environmental testing.

Round AM-19B was scheduled for launching between 1915 and 2045 EST August 12, 1959 on an azimuth of 44 deg. Approximately 2 weeks prior to launch the range indicated that 44 deg was not considered a safe azimuth; the azimuth was changed to 48 deg. Also, difficulties encountered with the cluster drive motors resulted in a 2-day delay in firing. Cluster and payload operations were considerably simplified for this flight since no assembly IV was necessary, and the payload was bolted to the assembly III cone. Figure 14 shows the payload and cluster assembly.

1. Cluster Preflight Preparation

Cluster 15 operations started at Cape Canaveral on July 13, 1959 with the preliminary inspection, at which time it was discovered that one of the leads to the accelerometer amplifier on stage 2 was damaged to the point of requiring replacement. The change of the drive motor gear system to a ratio of 15:1 to accommodate the cluster spin rate from 450 to 600 rpm had already been started in California. However, due to improper tolerances on some of the parts, ABMA personnel completed the work at the Cape. Considerable difficulty was encountered with the system, including motors wired backwards, loose parts in the filters, the filters themselves mounted backwards, and a faulty synchro.

After the gear change, the assembly of the cluster proceeded satisfactorily with the installation of the two dispersion accelerometers on assembly II, the alignment

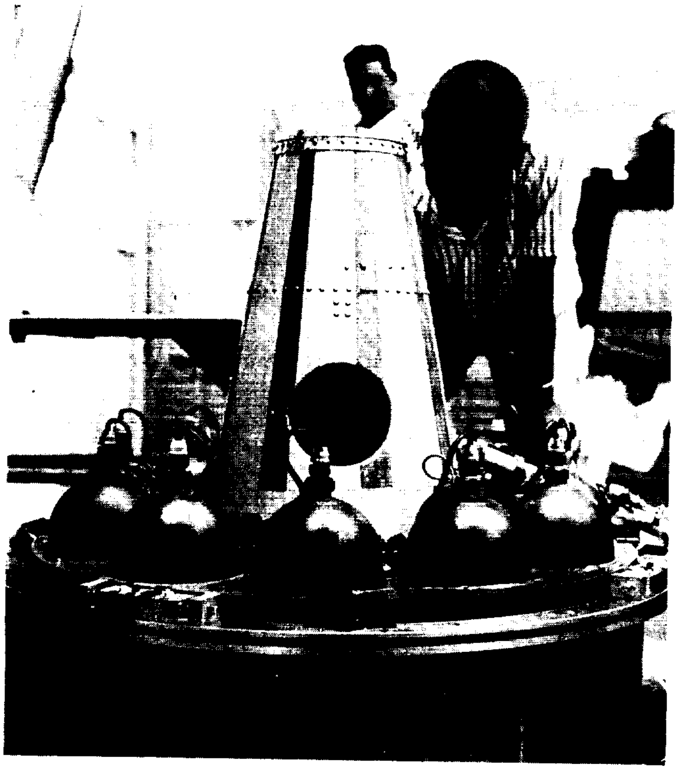


Fig. 14. Payload and cluster, AM-19B

and balance of assemblies II and III, electrical checkout, and motor and igniter checkout.

During the period between rf spin test and launch, it was necessary to install the heat-balance coatings. This consisted in painting white stripes on the payload so that 21% of the cylinder was covered, and also in adding gold-plated aluminum foil strips to the assembly III cone covering 31% of the surface.

2. RF Spin Test

The cluster was installed on the booster on August 6, 1959, after a minor delay for re-routing the cluster drive motor cables on the booster. The payload was installed and then the shroud. The shroud rf windows, which were originally designed for operation at 960 Mc, had been tuned to 108 Mc prior to the spin test. Installation of the shroud caused an approximate 8-db drop in signal strength as received at the Cape's Microlock station. This represented a satisfactory operating condition. There were several shifts in the beacon frequency, and although they did not occur during the actual spin test, the decision was made to exchange payload beacons.

At the time the spin test in which the cluster accelerated from 450 to 600 rpm, the cluster drive motor current exceeded 800 amperes total; the specified maximum was 700 amperes. Although the motors have in the past exceeded the maximum specified current, the power source has been incapable of supplying over 800 amperes. For this operation an additional battery had been added to the system. To correct this condition and still maintain the added capability of the two batteries required considerable effort and resulted in a 2-day postponement of the flight.

The assembly II dispersion accelerometers showed negative out-of-band signals all during the test. Immediately following the test, voltage measurements made on the amplifier package showed only 60% of normal. No other discrepancies were discovered, and it was believed that the low voltage was caused by either a short on the output or a voltage of opposite polarity applied to the output. The amplifier package was replaced, and although no more trouble was experienced, no satisfactory explanations were found.

3. Flight Operations

The countdown started at X − 720 min on August 14, 1959 without any built-in holds scheduled. Early in the count it was noted that two of the breakwire modules had their wires pulled out (one several inches), thus requiring replacement. No other difficulties were encountered during the cluster operation. A last-minute attempt was made to delay the firing time 30 min in order to improve the lighting conditions for photographing the flares that had been added to the instrument compartment. However, it was necessary to pick up time after only a 16-min hold in order to launch before a rain squall moved in. Liftoff occurred at 1931:00:7 EST.

The velocity of the first stage was determined to be approximately 5 to 10% low. To aid in optical tracking, a series of flares were to be fired from the guidance compartment. The first flare was fired at X + 180 sec; after which time, no further flares were observed or recorded. After X + 203 sec, telemetering records indicated a rapid reduction in the pressure within the guidance compartment. Pressurization of the guidance compartment is normally accomplished by a pressurized nitrogen bottle. This nitrogen bottle also serves as a gas supply for the guidance gyros bearing and attitude control jets. Because of the loss of guidance and the reduced velocity of the first stage, the velocity increments of the high-speed stages failed to put the payload into orbit.

4. Payload Design

The payload (Fig. 15) was a cylindrical configuration, having a diameter of 7 in. and a length of 31.5 in. The

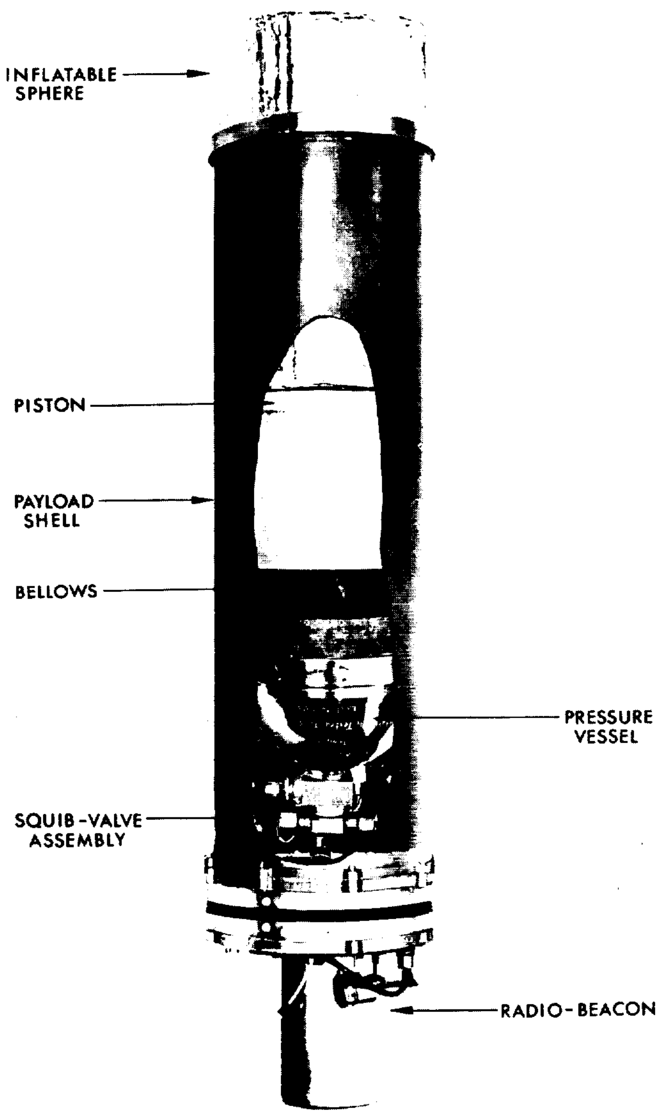


Fig. 15. Payload, AM-19B

major components were the payload shell, the beacon assembly, the pressure vessel, the squib-actuated valve assembly, the bellows and piston assembly, and the inflatable sphere. A prototype payload and three flight units were fabricated. However, only two flight units were readied for the launch date (August 14, 1959).

*a. **Beacon assembly.*** The beacon assembly (Fig. 16) consisted of a beacon rf transmitter assembly, a telemetry subcarrier oscillator assembly, a battery pack, and an antenna assembly. The power of the beacon exceeded 50 mw and utilized a battery pack containing 12 Mallory RM12-RT2 mercury cells.

The transmitter consisted of a crystal-controlled, transistorized oscillator operating at approximately 54 Mc. The oscillator was used to feed a transistorized power amplifier serving as a frequency doubler (108.03 Mc) which, in turn, fed the antenna. The modulation signal was derived from two transistorized subcarrier oscillators operating channels 3 and 4. Channel 3 was a resistance-controlled oscillator, having its frequency controlled by a thermistor located so that it would measure the transmitter temperature. This channel was also used to telemeter the inflatable sphere's ejection; this was accomplished by superimposing a step function of approximately 10 cps upon the temperature information. Channel 4 was a current-controlled oscillator used to telemeter the firing of the squibs that were to activate the pressure valve. The frequency step for this function was to be approximately 50 cps.

*b. **Balloon package.*** The inflatable sphere package consists of a pressure vessel and squib-actuated valve, a bellows and piston assembly, an inflation and release valve, and an inflatable sphere. The inflatable sphere was constructed of laminated Mylar (1-mil thick) sandwiched between two layers of aluminum foil (0.45-mil thick). The Mylar served as a gas barrier for the inflation process and as a support to which the aluminum foil layers could be bonded. The aluminum foil layers supplied the structural rigidity required to preserve the balloon's spherical shape after the inflation gases were bled off. As the sphere was not dependent upon internal pressure to retain its shape, the designed rigidity of the inflated sphere was several times greater than the amount of structural inflexibility necessary to resist the orbital environment loads to which it was to be subjected. The foil also provided a highly reflective surface for optical tracking. Figure 17 shows the inflated sphere fully formed, with its internal pressure normalized to atmospheric pressure.

The sequence of the inflation and release valve asembly is shown in Fig. 18. The position 1 condition shows the valve assembly just prior to the ejection process. The first event in the ejection process is the firing of the two squibs which actuate the pressure vessel valve. (This event is telemetered through channel 4 by the current-controlled oscillator sensing the electrical impulse which fires the squibs.) The pressure vessel valve then permits the pressurized nitrogen to expand the bellows, forcing the bellows piston to expel the packaged sphere. The extreme forward travel of the piston is then stopped by a wire rope attached to the inflation and release valve (position 2). The valve spring, then free to release part of its compression, draws the valve stem forward, open-

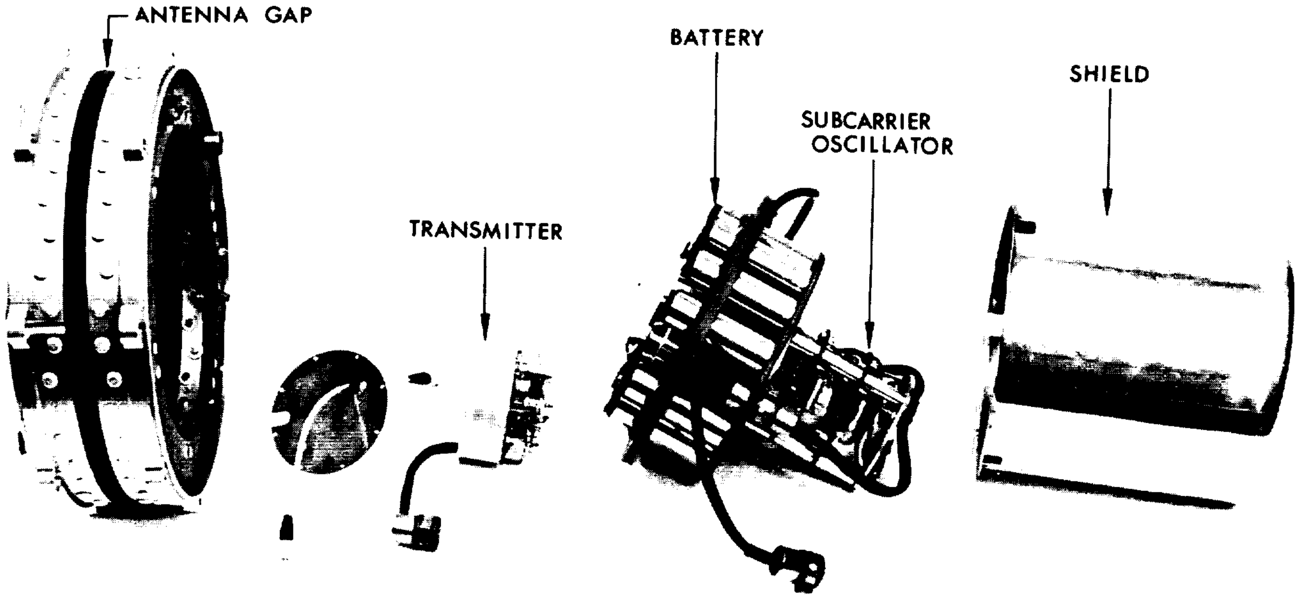


Fig. 16. Beacon assembly

Fig. 17. Twelve-foot inflatable sphere

ing the ball cock outlet port, and pressurized nitrogen begins to flow from the bellows, through the valve stem into the sphere (position 3).

The valve assembly components remain in this relationship until the sphere is completely inflated. The entire quantity of nitrogen is required to inflate the sphere, resulting in the draining off of the pressurized nitrogen in the bellows. In this condition the internal face of the bellows piston exerts a forward-moving force of about 3 lb. Being compressed between the outer sleeve and the valve stem, the valve spring overcomes the 3-lb force of the bellows piston and pushes the outer sleeve back to its starting position. The valve spring, now free to release, pulls the valve stem out of the inflation and release valve assembly, simultaneously imparting a separation energy to the satellite, and moving it ahead of the payload (position 4). Equalization of the internal pressure of the satellite to that of the external environmental pressure is provided through the open-valve stem of the satellite.

5. Dispersion Study

Telemetry data was taken during *Juno II* firings for the purpose of studying possible causes of trajectory dispersion due to mechanical interference. The mechanization of this study has been presented in Ref. 3 and 4.

Because the guidance compartment and cluster was tumbling at the time of the second-stage ignition, a poor telemetering signal was received. The vehicle antenna pattern was such that all stations except the TLM-18 telemetering station on the Cape lost the signal at the time of second-stage ignition. This station regained the telemeter signal at low level 2 sec before ignition and lost it 8 sec after ignition. Consequently, the data during this period was quite noisy. (Received signal strength records were not obtained for this round.)

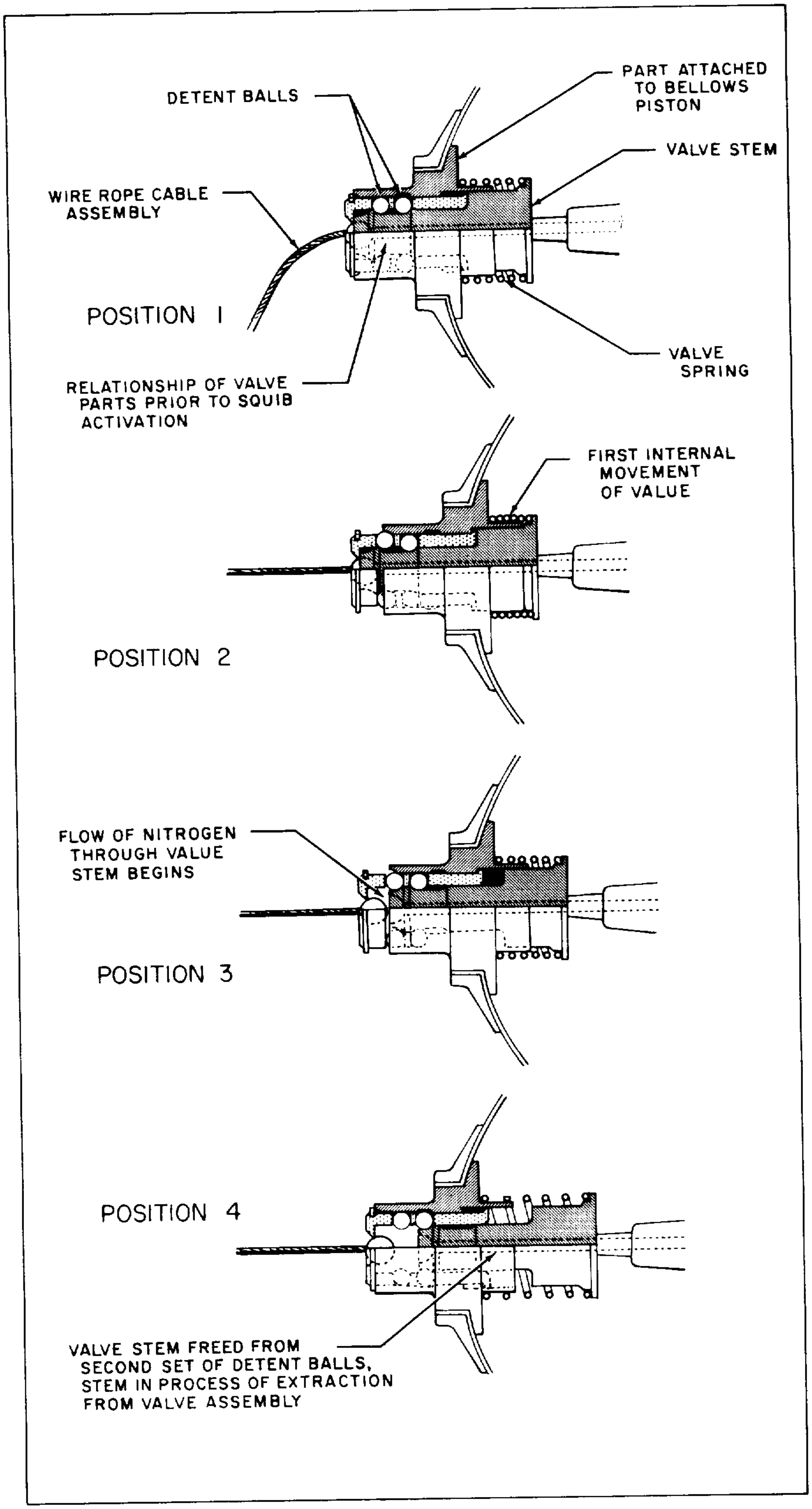


Fig. 18. Inflation role sequence

Evaluation of this data (Fig. 19) indicated an initial ignition shock in the vicinity of motor 10, and a saturation level bump in the vicinity of motor 2. The bump with a duration of approximately 30 millisec started shortly after the machined-surface release and ended shortly before the mid-bulkhead passed the lip of the tube. The data from this point until trailing-wire breakage (approximately the time the aft bulkhead passed the lip of the tube) indicated a vibration which was difficult to evaluate because of the noise level. This vibration level, however, stayed within the measurement range of ±50 g peak.

C. Juno II *(Round AM-19A)*

On October 13, 1959, *Juno II* Round AM-16A (19A) was launched successfully and resulted in placing a 92.5-lb multi-experiment satellite (Fig. 20) into a satisfactory orbit. This launching represented the second attempt to achieve this mission, the first attempt (AM-16) in July 1959, ending in failure because of a malfunction in the booster electrical system. Launching was delayed 12 days because of damage sustained by the booster (AM-19A) when *Jupiter* round AM-23 (launched September 16, 1959) was destroyed shortly after liftoff. Work was suspended on the cluster while awaiting word as to when the damage could be repaired. Pre-flight operations were started again on September 28 upon receiving word that the launching had been rescheduled for October 13. Payload integration and final preparation prior to moving to the pad were satisfactorily completed.

1. Preflight Preparation

Cluster 13, used for this flight, had been in storage at AMR since April. It was scheduled for use with a lighter payload and hence was not capable of supporting this heavier payload. It was determined that the cluster could most easily be modified by stiffening the fourth-stage motor case. However, it was desired that the modification not be directly attached to the fourth stage since this would subtract directly from payload weight. It was therefore decided to rivet a stiffening cylinder (Fig. 21) to the third-stage cone which would support the forward end of the fourth-stage motor case. An adapter (Fig. 22) on the fourth-stage motor case could then transfer the radial support to the head end

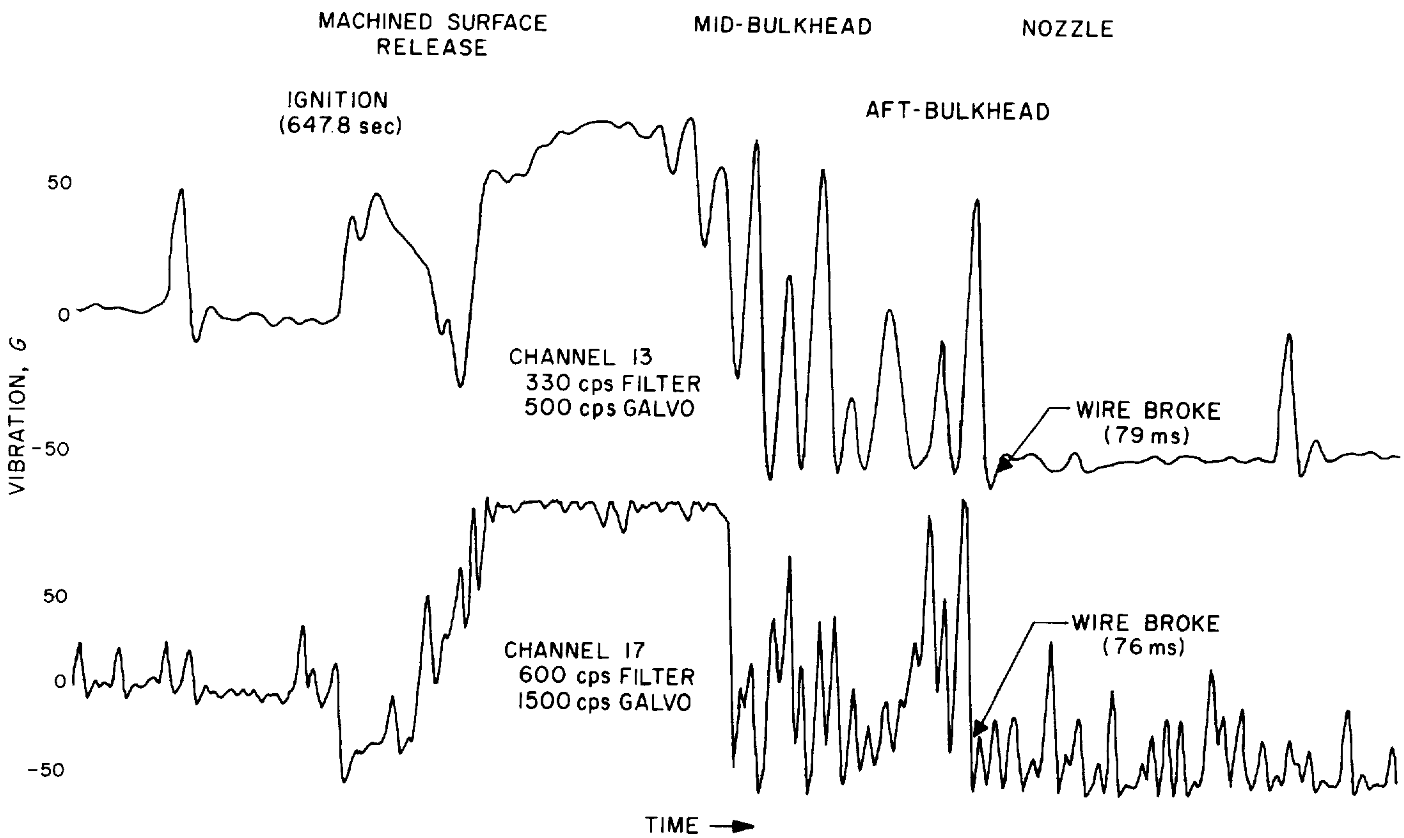


Fig. 19. Vibration data, AM-19B

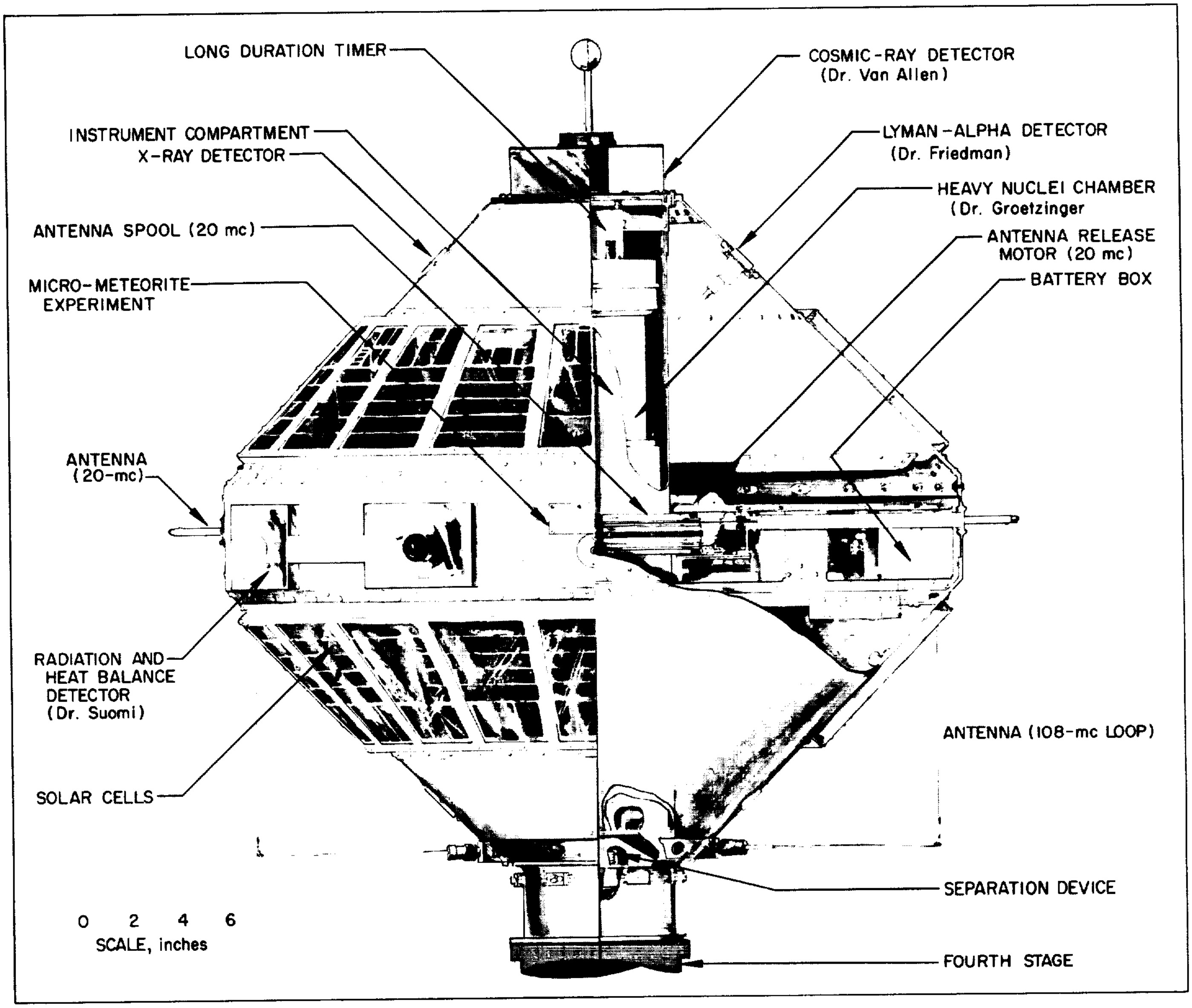


Fig. 20. Multipurpose payload experiment, AM-19A

of the cylinder. The adapter was fabricated and attached to the third and fourth stages without requiring any other major cluster changes.

The modification successfully accomplished, final assembly and checkout of the cluster started on August 28, 1959 at AMR. Visual inspection and pressure check of the motors gave no indication of any damages due to shipping or the long storage period. After the installation of each assembly in the launcher, alignment and balance were checked and reduced to a minimum. After the entire cluster was balanced and shear-pinned, the runouts taken on the head end of the fourth-stage motor were less than 0.001 in, both in perpendicularity and concentricity.

*a. **RF interference test.*** On October 7, 1959, the cluster was mated with the booster and preparation made for the rf interference test. This test performed with all rf equipment operating, and the cluster spinning did not show up any interference difficulties. Upon examination of the telemetering records it was noticed, however, that the armature current on one of the cluster drive motors was excessive during cluster acceleration periods. This condition was improved by deliberately unbalancing the field currents of the two motors. During the spin test, satis-

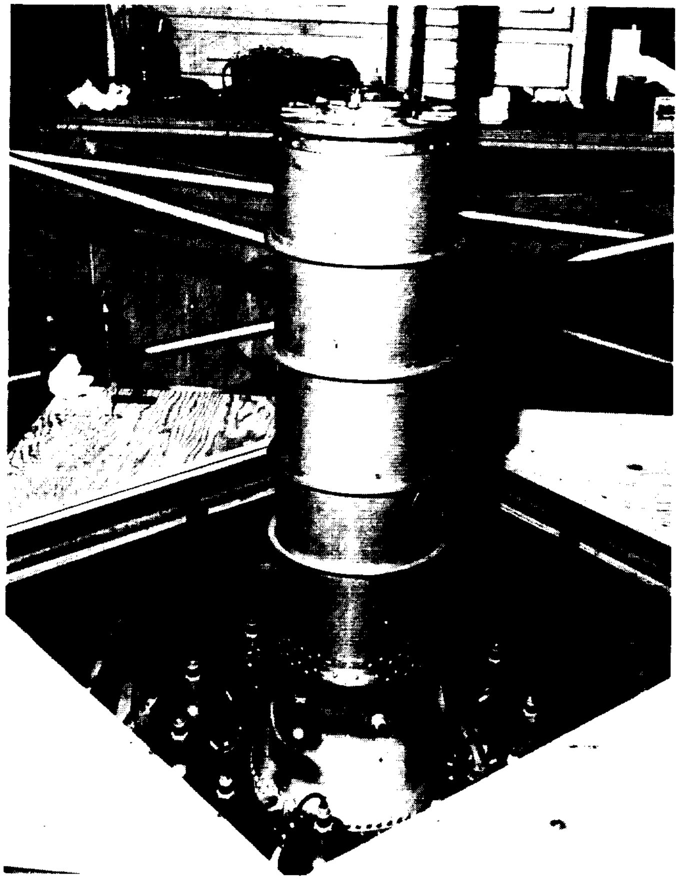


Fig. 21. Modified third stage

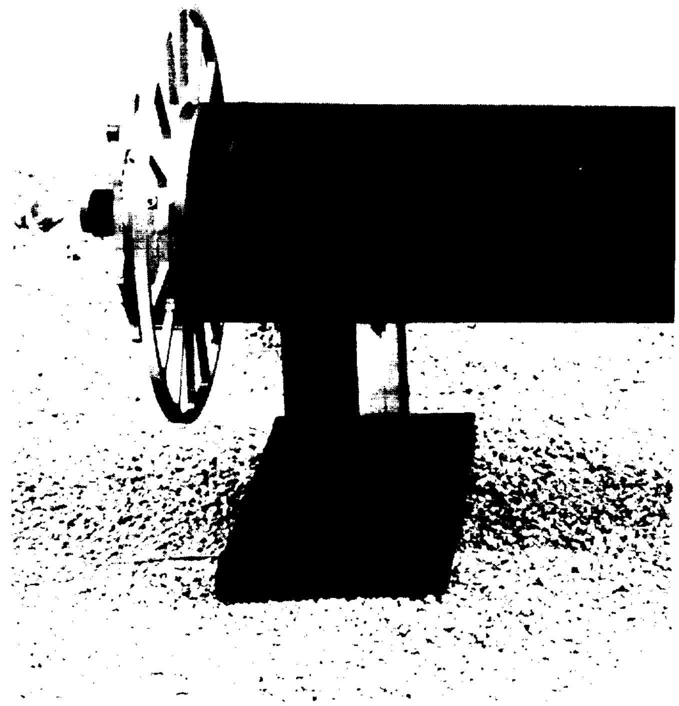


Fig. 22. Fourth stage support adapter

factory operation of the cluster accelerometers was also indicated.

b. Flight test. The final countdown commenced at 2150 hr, October 12 at X − 700 min. In addition, a 1-hr hold was scheduled at X − 31 min in order to assure launching during the allotted 2-hr firing window. The countdown operations progressed with only minor difficulties, although the presence of several lightning storms in the general area caused considerable apprehension as to whether it would be necessary to stop work. Fortunately, the disturbances did not move in closer than the 1.5-km safety radius, and countdown operations continued. At X − 45 min, 4 min of the built-in hold were utilized in order to clear the pad area prior to turning on all rf again. The remainder of the hold was used at the scheduled time of X − 31 min. No further holds were necessary and liftoff occurred at 10:30:14.25 EST on October 13, 1959.

c. Results. Preliminary information indicated that all flight operations were successful with only minor deviations in velocity and angle. This was later confirmed by the early orbit determination at ABMA. Information, based upon injection conditions that were obtained by fitting all doppler data available from launch and the first two orbital passes, Goldstone angle data from the second pass, and optical sighting from San Fernando, Spain, and Woomera, Australia, is shown in Table 20 of Ref. 5.

2. Dispersion Study

The first stage performed normally as expected, providing a greater signal strength than that of the previous round. However, commencing at second-stage ignition and for the duration of the measurement, signal strength dropped slowly from 1400 to 350 μv. About the time the aft bulkhead passed the lip of the tube, signal strength jumped to a level of 1100 μv where it remained for about 90 millisec before dropping to 350 μv. This malfunction was apparently caused by the flame around the telemetering antennas located on the sides of the guidance compartment.

The data (Fig. 23) from this round indicates an initial shock in the vicinity of motor 5 and a saturation level bump (approximately 50-millisec duration) in the vicinity of motor 2. This bump started shortly after the machined-

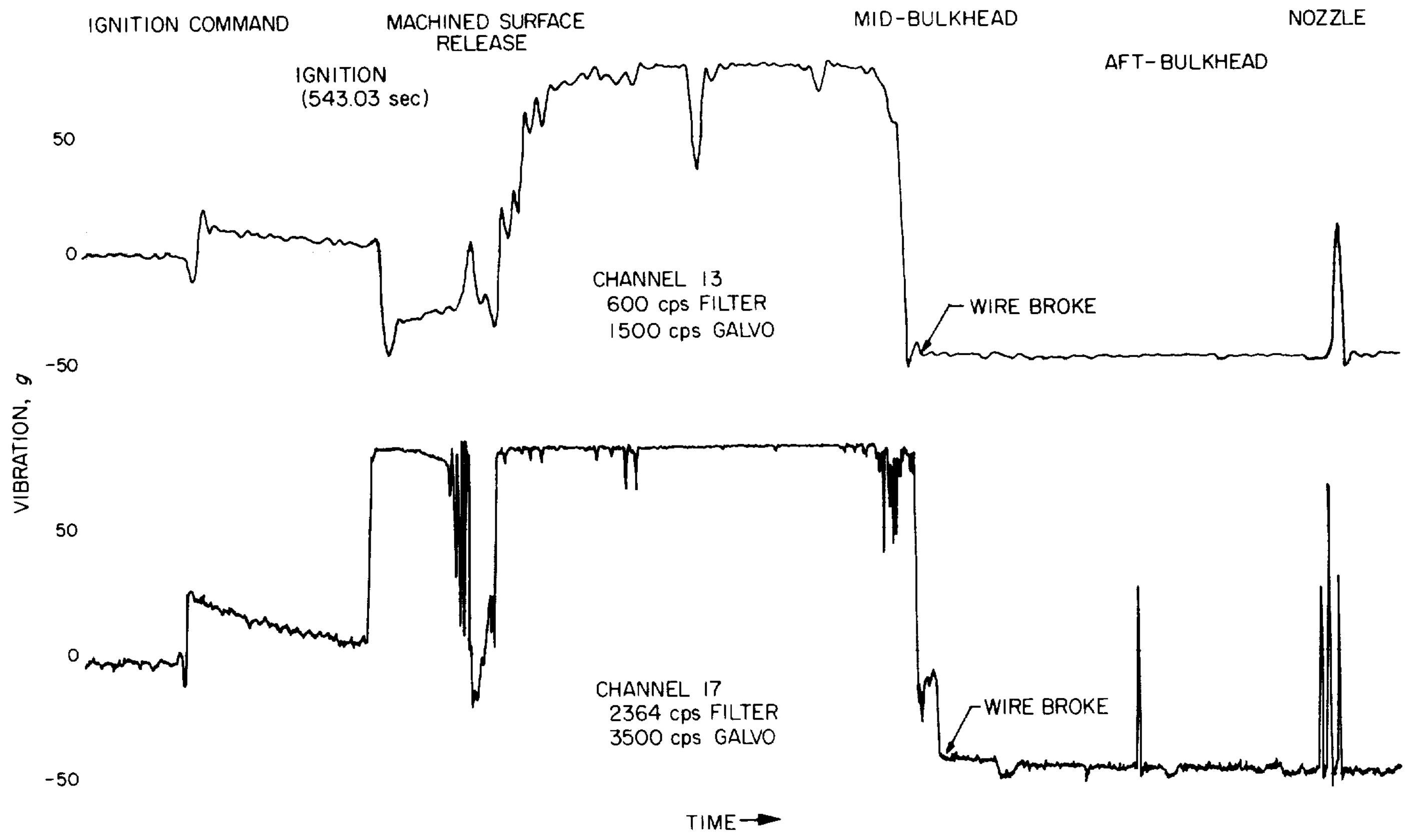


Fig. 23. Vibration data, AM-19A

surface release and ended shortly before the mid-bulkhead passed the tube lip, with the trailing wires breaking shortly after this point.

D. Round AM-19C Launching

On March 23, 1960, *Juno II* round AM-19C was launched in an unsuccessful attempt to place the S-46, 22.5-lb Van Allen payload (Fig. 24) into a highly elliptical orbit.

The payload for round AM-19C was designed to monitor the radiation intensity distribution of the two Van Allen radiation zones over an extended period of time with the objective of establishing the origins, including buildup and decay of radiation, in the two zones and correlating this with solar activity. In addition, the experiment was designed to study the composition of radiation in the two zones, to determine the nature of penetrating components and the energy spectrum of the less penetrating components, and to measure the total energy flux throughout the region of trapped radiation with special interest placed on the outer reaches.

Booster performance was essentially nominal; however, stage 2 fired under a mean angle of 19 deg down and 5 deg right from nominal with approximately correct performance. This large angle of the second stage is very unusual and exceeded all other observed stage 2 deviations on previous rounds. From this performance it was concluded that there was a cluster malfunction.

JPL cluster 16 was used on this round, and its configuration was essentially that of early *Juno II* rounds (AM-11 and AM-14 used on the *Pioneer* series; see Fig. 25). It did not have the stage 3 cylindrical support that was flown on rounds 19A and 16A. There were two reasons for this: first, the payload was very light (22.5 lb), and therefore the cluster did not require the additional structural stiffening; second, the orbit requirements were such that the extra 10 lb of cylindrical support weight on stage 3 could not be afforded.

This cluster was delivered to Cape Canaveral on December 3, 1959, and stored until February 16, 1960, when it was sent to the JPL spin building for flight preparation. Initial spin tests for AM-19C were accomplished satisfactorily on March 15, 1960.

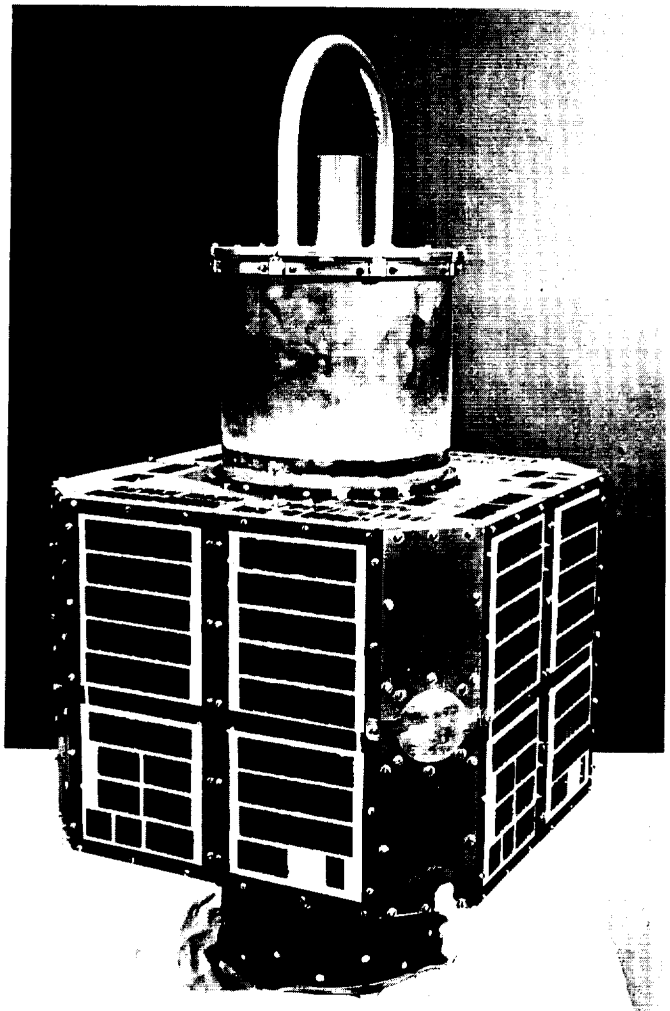


Fig. 24. Payload-Van Allen radiation experiment, AM-19C

Although much effort was expended in an attempt to pinpoint the cause of malfunction of the high-speed stages, no conclusive explanation could be obtained. One-motor-out performance of the second stage was examined and found to fit the flight performance reasonably well.

E. Round AM-19D Launching

On November 3, 1960, the *Juno II* AM-19D vehicle placed into orbit the artificial satellite S-30, *Explorer VIII*, instrumented to study and report the temporal and spatial distribution of the ionospheric parameters existing between 200 and 1200 km above the Earth. The correlative data to be taken was comprised of measurements of the charge accumulations on the surface of the satellite and the relation of this data to electrical drag and density of the medium, and measurements of the frequency, momentum, and energy of micrometeorite impacts.

Both the *Jupiter* booster and JPL cluster performed close to preflight predictions, as shown in Table 5. JPL cluster 17 (Fig. 26) used on this round was identical to the cluster used on Round AM-19A (or 16A) with a support cylinder added to the stage 3 cone. This cylinder was again required because payload weight was in the range of 92.5 lb, and the cluster needed the additional rigidity.

This cluster was delivered to Cape Canaveral on May 2, 1960, and stored in the AMR magazine until September 27, 1960, when it was delivered to the JPL spin building for final assembly. By October 25, 1960, the cluster assembly work and payload mating had been completed, and the cluster was sent to the pad for mating with the *Jupiter*. The initial spin test was then conducted satisfactorily as was the plug drop test in which fuzes (simulating stage 2 igniters) were fired through the composite *Jupiter* cluster wiring.

Fig. 25. Cluster configuration, AM-19C

Table 5. Orbit characteristics of *Explorer VIII*

Characteristic	Predicted	Actual
Perigee, km	395	370
Apogee, km	2375	2341
Eccentricity, km	0.1276	0.1275
Inclination, deg	50.33	49.9
Period, min	113.3	112.7

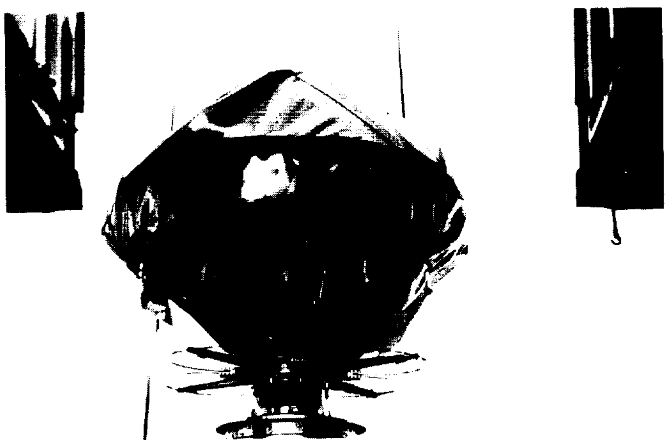


Fig. 26. Cluster configuration, AM-19D

The countdown on October 3, 1960, was marred only by the necessity of removing the payload for a minor repair after it had been mated to the cluster. However, the repair was made, the payload remounted on the cluster, and the launching successfully executed within the allowed firing window.

F. Round AM-19F Launching

On February 24, 1961, *Juno II* AM-19F (Fig. 27) was launched in an unsuccessful attempt to place the 75-lb S-45 ionosphere beacon satellite (Fig. 28) into orbit. The payload for AM-19F was designed to provide a means to study the propagation of signals through the ionosphere. These signals would enable the acquisition of data relative to ionospheric absorption anomalies, integrated electron density, faraday rotation measurements, and a possibility of transmission time delays.

As detailed in Table 6, booster performance was essentially normal until first separation (booster tankage from instrument compartment). While evidence is inconclusive, a possible mode of failure is that the cable from the angle-of-attack meter (shown in Fig 29) came free from the side of the shroud (held in place only by a potting compound) and interfered with the rotation of the payload. This interference led to the displacement of the payload, the unseating of stage 4, the destruction of the stage 3 and 4 timer, and eventually to the loss of

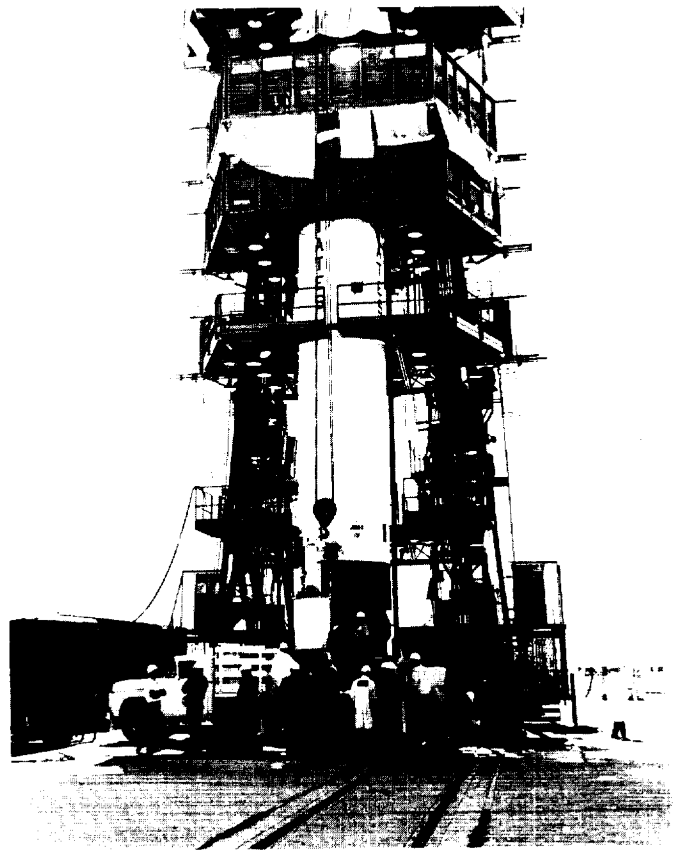


Fig. 27. *Juno II*, AM-19F

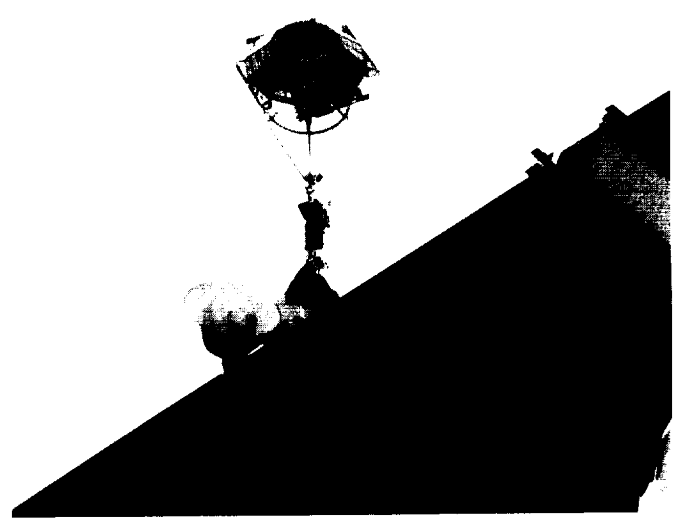


Fig. 28. Payload, AM-19F, ionosphere beacon

Table 6. Initial data on round AM-19F

Event	Predicted time, sec	Range time, sec	Universal time
Range-zero time[a]	0	0	1913:13
Liftoff time (first vertical movement of vehicle)	0	0	1913:13
Booster: cutoff	179.3	178.5	1916:11.5
Booster: separation	186.3	186.5	1916:19.5
Signal from angle-of-attack measurement lost	–	188.1	–
Pitch and yaw gyros start to oscillate at 3 to 4 cps	–	188.1	–
Cluster drive motor currents go to full scale	–	188.7	–
Platform rolls greater than 15 deg (essentially lose reference)	–	190.3	–
Payload transmitter signal lost	–	204	–
Shroud separation (no indication of shroud kick motor firing)	214	214	1916:47
Cluster dynamic condition returns to normal	–	221	–
Stage 2 ignition	432	473	1921:6
Stage 3 ignition			Not observed
Stage 4 ignition			Not observed
Launch azimuth			44 deg East of true North

[a]The instant chosen as range-zero time is the first whole-number second occurring immediately prior to liftoff.

spatial attitude control of the instrument compartment. This theory is supported by the dynamic condition of the cluster returning to normal shortly after the ejection of the shroud (possibly permitting the escape of the unseated stage 4 and payload).

Stage 2 was observed to fire (with approximately correct performance) by the Lincoln Laboratory radar facility; however, netither stage 3 nor stage 4 was observed to fire, supporting the theory that the timer was destroyed.

Another possible mode of failure is that stage 3 to stage 4 shear pins failed prematurely due to negative *g* loads. After considerable investigation this possibility was judged highly improbable, and no changes have been made in the method of shear-pinning the high-speed stages. The criteria governing shear pin strength and design were again reviewed and judged adequate for the existing cluster dynamic environment.

JPL cluster 19 used on this round was identical to cluster 17 used on AM-19D. Prior to the launching of this vehicle, the JPL engineering review team expressed interest in obtaining test information on the second-stage ignition level and squib time delay as a function of the combined cluster-*Jupiter* circuitry. To obtain this information, simulated igniters (identical to flight igniters with the exclusion of pyrotechnic material) were connected to the stage 2 harness. An oscilloscope was also connected into this harness and equipped with a polaroid camera to record the ignition sequence. Figure 30 shows the actuation time of the eleven igniter simulators, and it can be seen that there was approximately a 4-millisec time period from power first being supplied until the

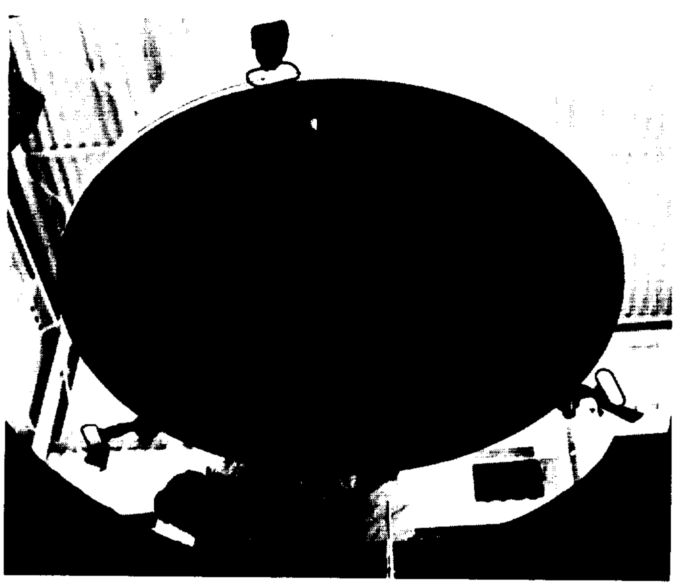


Fig. 29. Shroud, AM-19F

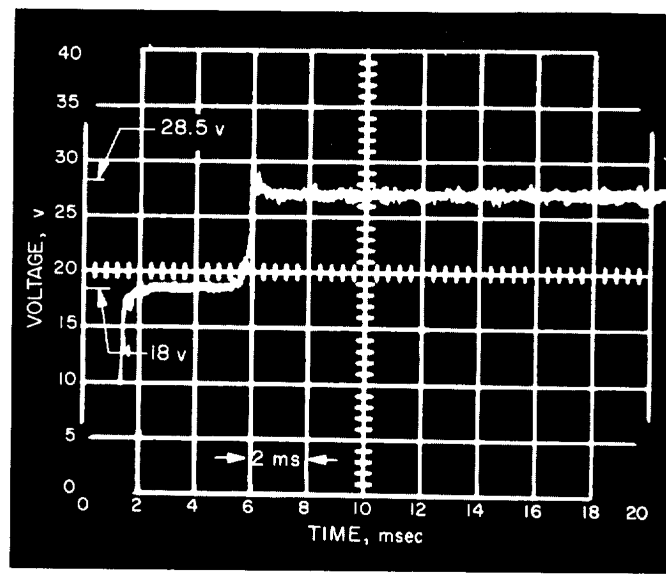


Fig. 30. Second stage ignition characteristics

first squib was activated. The remaining 21 squibs all fired within a 0.5-millisec time period. The voltage rose from approximately 18 v with full squib load to 28.5 v for no load. The important time period (as far as stage 2 ignition is concerned) is from the time the first squib ignites until the last squib ignites. In this particular case the 0.5-millisec time period is acceptable considering the fact that stage 2 maintains electrical contact for 12 millisec under full thrust conditions.

G. Round AM-19E Launching

On April 27, 1961, the *Juno II* AM-19E vehicle placed into orbit the artificial 85-lb satellite S-15, *Explorer XI*, the gamma-ray astronomy satellite. This satellite (Fig. 31) has the primary objective of detecting and mapping the high-energy gamma rays resulting from neutral pimeson (pion) decay and relating this data with the density of cosmic-ray flux and interstellar matter. The secondary objective is to measure the ratio of the high-energy gamma rays reflected by the Earth's atmosphere to the quantity of gamma rays falling upon the Earth.

Both the *Jupiter* booster and the JPL cluster performed close to preflight predictions, as shown in Table 7. JPL cluster 18 used on this round was identical to the cluster used on 19D. The countdown proceeded smoothly without interruption with the exception of a 5-min hold at X − 15 min for an AMR computer check.

Table 7. Orbit characteristics of *Explorer XI*

Characteristic	Predicted	Actual
Perigee, km	475	497
Apogee, km	1832	1793
Inclination, deg	28.307	28.49
Period	108.06	108.1

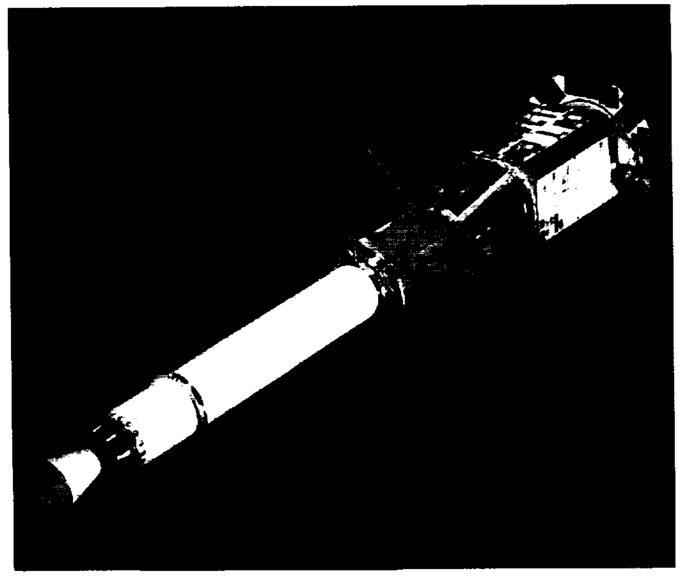


Fig. 31. Gamma ray astronomy satellite, AM-19E

H. Round AM-19G Launching

This was the last vehicle in the *Juno II* series and was unsuccessfully launched on the afternoon of May 24, 1961. The payload for this vehicle was again (see AM-19F) S-45, the ionosphere beacon.

Following takeoff, all vehicle functions were normal until after booster burnout and first separation (instrument compartment from thrust unit). During the coasting phase, the power supply in the instrument compartment failed, thereby cutting off all equipment dependent upon that power. The cluster ignition signal was dependent on this power supply and as a consequence, stage 2 of the missile never received ignition current and so failed to fire.

V. CONCLUSIONS

A. Vehicle Performance

1. There were nineteen launchings in the RTV and *Juno* programs. Out of these nineteen launchings, there were eighteen opportunities for the three-stage high-speed cluster system to function. Of these opportunities to function, sixteen unquestionably performed successfully; six of these performing successfully failed to achieve mission objectives because of unfavorable initial conditions caused by malfunctions of the booster or instrument compartment. These launchings resulted in eight significant satellites and two space probes as shown in Table 8.
2. A total of 296 *Sergeant* scale motors were cast for flight purposes (including space stage 4 motors), and 180 of these motors were properly positioned in space and supplied an ignition signal. As stated before, two of these motors failed to function, resulting in the loss of two missions.
3. In addition to the 296 flight motors, approximately 450 additional research and development units were produced. These motor units were used to evaluate hardware components, ignition systems, various propellant compositions, simulated flight loads, and propellant aging characteristics. No failures or detrimental effects of any type were encountered during the final flight motor evaluation phase.
4. Two of the nine failures in the RTV, *Juno I*, and *Juno II* programs are attributable to malfunction of the high-speed stages. On *Juno I* round 26, the fourth stage failed to fire and on the *Juno II* round AM-19C, one motor in the second stage probably failed to ignite. Examination of mode of failure on round 26 led to a component redesign on the fourth-stage motor igniter support, and this type of failure never recurred. The failure of the second stage motor on round AM-19C was never exactly understood, and no corrective design action was undertaken. However, this failure did motivate everyone concerned to review the system (power supply, wiring, voltage level at the stage 2 igniters, etc.). Again this particular mode of failure never recurred.

B. Mission Accomplishment

Essentially the *Juno* program accomplished all its major objectives. First, it successfully completed its re-entry nose cone testing mission. Second, the *Juno I* program placed *Explorer I* and other significant satellites (18-to-30-lb class) into orbit. Thirdly, the *Juno II* space probe program boosted the first U.S. space probe in an orbit around the Sun, obtaining valuable trajectory and communication data, and lastly, in the *Juno II* Earth satellite program, it successfully completed 3 of 6 assigned missions.

Table 8. Summary of successful launchings

Program	Flight or round and date	Duplicate designations	Stages	Mission	Results
RTV	Round 27, *Jupiter C* 9/20/56		3	Proof test of re-entry test vehicle and Microlock	Successful Range: 3300 mi. Height: 650 mi.
RTV	Round 40, *Jupiter C* 8/8/57		3	Re-entry nose cone test	Successful recovery of nose cone
Juno I	Round 29, *Jupiter C* 1/31/58	*Explorer I* 1958 Alpha	4	Earth satellite	Successfully orbited
Juno I	Round 24, *Jupiter C* 3/26/58	*Explorer III* 1958 Gamma	4	Earth satellite	Successfully orbited
Juno I	Round 44, *Jupiter C* 7/26/58	*Explorer IV* 1958 Epsilon	4	Earth satellite	Successfully orbited
Juno II	Round AM-11 12/6/58	*Pioneer III* *Juno IIA*	4	Space probe	63,500-mi. apogee
Juno II	Round AM-14 3/3/59	*Pioneer IV* *Juno IIA'*	4	Space probe	In orbit around Sun
Juno II	Round AM-19 A 10/13/59	IGY Satellite *Explorer VI*	4	Earth satellite	Successfully orbited
Juno II	Round AM-19 D 11/3/60	*Explorer VIII*	4	Earth satellite	Successfully orbited
Juno II	Round AM-19 E 4/27/61	*Explorer XI*	4	Earth satellite	Successfully orbited

REFERENCES

1. Wolfe, Allen E., and William J. Truscott, *Juno Final Report. Volume I. Juno I: Re-entry Test Vehicles and Explorer Satellites,* Technical Report No. 32-31, Jet Propulsion Laboratory, Pasadena, California, September 6, 1960 (CONFIDENTIAL).

2. Wolfe, Allen E., *Juno Final Report. Volume II. Juno II: Space Probes,* Technical Report No. 32-31, Jet Propulsion Laboratory, Pasadena, California, September 12, 1960 (CONFIDENTIAL).

3. *Space Programs Summary No. 2,* Jet Propulsion Laboratory, Pasadena, California, April 1, 1959 (CONFIDENTIAL).

4. *Space Programs Summary No. 4,* Jet Propulsion Laboratory, Pasadena, California, August 1, 1959 (CONFIDENTIAL).

5. *Space Programs Summary No. 6,* Jet Propulsion Laboratory, Pasadena, California, December 1, 1959 (CONFIDENTIAL).